Renewable and Sustainable Energy Reviews 16 (2012) 5007–5020

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

# Prospects of biodiesel from Jatropha in Malaysia

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ARTICLE INFO

*Article history:*
Received 12 December 2011
Received in revised form
2 May 2012
Accepted 3 May 2012
Available online 27 June 2012

*Keywords:*
Renewable energy
Malaysia
Biodiesel
*Jatropha curcas*
Environment
Stability

ABSTRACT

The increasing energy demands along with the expected depletion of fossil fuels have promoted to search for alternative fuels that can be obtained from renewable energy resources. Biodiesel as a renewable energy resource has drawn the attention of many researchers and scientists because its immense potential to be part of a sustainable energy mix in near future.

This report attempts to compile the findings on current global and Malaysian energy scenario, potential of biodiesel as a renewable energy source, biodiesel policies and standards, practicability of *Jatropha curcas* as a biodiesel source in Malaysia as well as impact of biodiesel from *Jatropha curcas*. Final part of this report also describes the development of biodiesel market in Malaysia.

The paper found that *Jatropha curcas* is one of the cheapest biodiesel feedstock and it possesses the amicable fuel properties with higher oil contents compared to others. Being non edible oil seed feedstocks it will not affect food price and spur the food versus fuel dispute. Jatropha can be substituted significantly for oil imports. Jatropha biodiesel has potential to reduce GHG emission than diesel fuel and it can be used in diesel engine with similar performance of diesel fuel. *Jatropha curcas* has an immense contribution to develop rural livelihoods too. Finally biodiesel production from Jatropha is eco-friendly and offers many social and economical benefits for Malaysia and can play an increasingly significant role to fulfill the energy demand in Malaysia.



**Contents**



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http://dx.doi.org/10.1016/j.rser.2012.05.010

## 1. Introduction

Energy is the primary input for evolution of all branches of modern economics [1]. As in consequences the global energy consumption is growing likely to faster than the population. The global primary fuel consumption has grown from 6630 million tons of oil equivalent (Mtoe) in 1980 to almost double 12,002.4 Mtoe in 2010. According to the estimation done by International Energy Agency, a 53% increase in global energy consumption is foreseen by 2030 [2]. The energy consumption is mainly fossil fuels which account for 87% amongst which crude oil consisting of 33.57%, coal 29.62% and natural gas 23.81%. However the share of Nuclear Energy, Hydropower and Renewable energy are very small with only 5.22%, 6.46% and 1.32% of total energy usage, respectively [3].

At present, energy security is an increasingly critical issue due to the ascending demand for energy in outbound countries and prospective fossil fuel dearth. That's why the renewable and new energies are becoming one of the key energy sources in the world. Currently, the contribution of renewable energy only 11% of the total global energy used [4]. In both developing and industrialized countries biofuels are at the top of their agendas and world biofuels production is expected to rise quadruple by 2020 [5]. It is reported that biodiesel is one of the mutual types of biofuels in the world. As an alternative fuel biodiesel is the better choice because of the capability of reducing green house gas emissions. Biodiesel is biodegradable, renewable and non-toxic [6–12] which have huge potential to be a part of a sustainable energy mixes in the future [13,14]. Globally, annual biodiesel production increased from 15,800 barrel per day in 2000 to 291,000 barrel per day in 2009 and consumption has also increased from 8.40 thousand barrel per day to 281.63 thousand barrel from 2000 to 2009 [15].

It has been found that total population in Malaysia rose from 18 million in 1990 to 28 million in 2010 [16]. Indeed oil, natural gas, coal, hydropower and biomass are the primary energy resources in Malaysian energy supply. According to British petroleum statistics; in Malaysia primary energy consumption has increased from 48.6 Mtoe in 2001 to 62.9 Mtoe in 2010 at an average increase of 3.6% per anum. Oil production in Malaysia has decreased from 32.9 Mton in 2001 to 32.1 Mton in 2010 and the corresponding consumption has increased from 22 Mton in 2001 to 25.3 Mton in 2010. Unlike oil, natural gas production has increased from 42.2 Mtoe in 2001 to 59.8 Mtoe in 2010 and the corresponding consumption has also increased. The final energy demand in Malaysia is growing considerably from 33.9 Mtoe in 2003 to 83.5 Mtoe in 2020, at a rate of 5.4% per annum. In Malaysia, annual biodiesel production has been increased from 1.1 thousand barrel per day in 2006 to 5.7 thousand barrel per day in 2009 at an average increase of 26.6% per anum [15] which is mainly from edible oil sources. Now a day, worldwide attention has been drawn to the potential of using biodiesel from non edible oil sources such as Jatropha [17]. It is reported that Jatropha is one of the best candidates for future biodiesel production [18]. Malaysia has adequate area of land and good climatic condition which can promote the cultivation of Jatropha to be one of sources of biodiesel production. Malaysia is taking on the challenge to further explore and strengthening the Jatropha production initiative through partnership with the government agencies and with private sectors. This effort is a vision to set Malaysia to the forefront of the global alternative fuel producers. In Malaysia it is anticipated that production of biodiesel will grow significantly in the succeeding years due to the handiness of mass biodiesel feedstock such as palm oil and *Jatropha curcas* [19,20].

The plant Jatropha has a number of strengths. The oil of Jatropha is highly suitable for producing biodiesel and it also can be used directly to power suitably adapted diesel engines. It can be used as a source of light in remote areas as well as heating source for cooking.

## 2. Potential of biodiesel as a renewable energy source

The specification and technical regulation of biodiesel are set by USA as ASTM 6751- 02 or by the European Union as EN 14214 [21]. Table 1 [19,22–29] shows the detailed ASTM D6751 and EN 14214 biodiesel specifications. Biodiesel is an ester based oxygenated fuels consisting of long chain fatty acids which is derived from vegetable oils (both edible and non–edible) or animal fats [30,31]. Its name indicate that it can be used in diesel engine as alternate without major modification of the engine with same or better performance in comparison to ordinary diesel fuel [12,32]. Biodiesel can be produced from vegetables oils in four different ways namely pyrolysis/cracking, dilution with hydrocarbons blending, emulsification, and transesterification [22,33–36]. Transesterification seems to

**Table 1**
ASTM D 6751–02 and EN 14214 specifications for biodiesel without blend.
*Source*: [19,22–29].

| Properties | ASTM D 6751 | | EN 14214 | |
|---|---|---|---|---|
| | Limit | Method | Limit | Method |
| Density at 15 °C | 870–890 kg/m$^3$ | ASTM D4052-91 | 860–900 kg/m$^3$ | EN ISO 3675, EN ISO 12185 |
| Flash point | 130 °C minimum | ASTM D93 | > 101 °C (minimum) | EN ISO 3679 |
| Viscosity @ 40 °C | 1.9–6.0 mm$^2$/s | ASTM D445 | 3.5–5.0 mm$^2$/s | EN ISO 3140 |
| Sulfated ash | 0.020% m/m maximum | ASTM D874 | 0.02% m/m (maximum) | EN ISO 3987 |
| Cloud point | Report to customer | ASTM D2500 | Based on national specification | EN ISO 23015 |
| Copper strip corrosion | Class 3 maximum | ASTM D130 | Class 1 rating | EN ISO 2160 |
| Cetane number | 47 (minimum) | ASTM D613 | 51 (minimum) | EN ISO 5165 |
| Water content and sediment | 0.050 (%v) maximum | ASTM D2709 | 500 mg/kg (maximum) | EN ISO 12937 |
| Acid number | 0.50 mg KOH/g maximum | ASTM D664 | 0.50 mg KOH/g (maximum) | EN 14104 |
| Free glycerin | 0.02% (m/m) maximum | ASTM D6584 | 0.02% (m/m) (maximum) | EN 1405/14016 |
| Total glycerol | 0.24% (m/m) maximum | ASTM D6548 | 0.25% (m/m) | EN 14105 |
| Methanol content | 0.20% (m/m) maximum | EN 14110 | 0.20% (m/m) (maximum) | EN 14110 |
| Phosphorus | 10 mg/kg maximum | ASTM D4951 | 10.0 mg/kg (maximum) | EN 14107 |
| Distillation temperature | 360 °C | ASTM D1160 | – | – |
| Sodium and Potassium | 5.00 ppm maximum | EN 14538 | 5.00 mg/kg (maximum) | EN 14108, EN 14109 |
| Oxidation stability | 3 h minimum | EN ISO 14112 | 6 h (minimum) | EN ISO 14112 |
| Carbon Residue | 0.05 maximum wt% | ASTM D 4530 | 0.30% (m/m) (maximum) | EN OSO 10370 |
| Calcium and Magnesium | 5 ppm maximum | EN 14538 | 5 ppm (maximum) | EN 14538 |
| Iodine number | – | – | 120 giod/100 g (maximum) | EN 14111 |

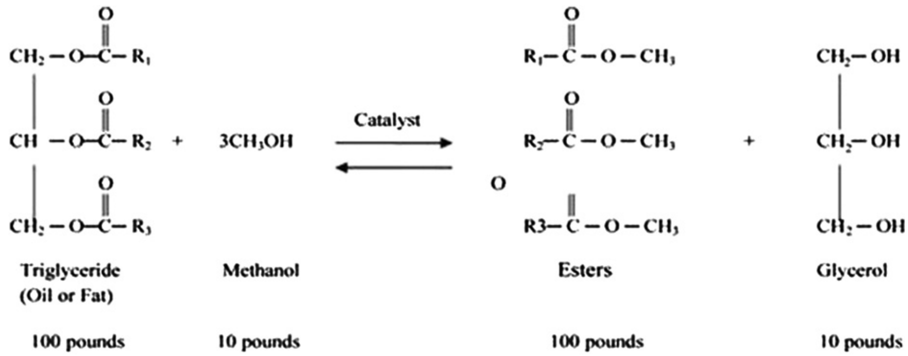



**Fig. 1.** Chemical Reaction of Transesterification process.

be the most common method among other process to convert oil into biodiesel. This process widely uses to reduce the viscosity of triglycerides [37,38]. The entire transesterification process can be represented by three steps. First oils is turn into esters, second filtering mean separating out the glycerin and lastly the glycerin sinks to the bottom and the biodiesel floats on top which can be siphoned off. One hundred pounds of fat/oil are reacted with ten pounds of a short chain alcohol in the presence of a catalyst to produce ten pounds of glycerin and one hundred pounds of biodiesel. As per the transesterification reaction, three mole of methanol were required to react with one mole of vegetable oil as shown in Fig. 1 [19,22,23,36,37,39–41]. Catalytic transesterification process is the most commonly used process. Therefore three types of catalytic transesterification can be used; namely alkaline catalysts, acid catalyst and enzymes. It has been reported that among all catalytic reaction alkaline catalyst is fastest and most frugal method [22,39,40,42]. However, acid-catalyzed reaction increases the yield in esters. In this reaction, main by-product is glycerol which further can be used in the cosmetic industry as a feedstock [43]. As alternative fuel the use of vegetables oil has been initiated by the inventor of the diesel engine around since 1900 and he first tested his compression Now Biodiesel is also being used in developed countries like Europe and USA to minimize the pollution of air and to minimize the dependency on consuming fossil fuel which price is hiking day by day [44]. Biodiesel does not contain any petroleum products but biodiesel is sequacious with ordinary diesel and make a stable blend when blended with diesel in any ratio in a compression ignition engine. Therefore, at present biodiesel is one of the mutual types of biofuels in the world. The key milestones for the development of biodiesel industry in different countries are shown in Table 2 [23].

**Table 2**
Key milestones for the development of biodiesel industry in different countries.
*Source*: [23]

| Date | Event |
|---|---|
| August 10, 1893 | Rudolf Diesel's prime diesel engine model, which was fueled by peanut oil, ran on its own power for the first time in Augsburg, Germany. |
| 1900 | Rudolf Diesel showed his engine at the word exhibition at the world exhibition in Paris, his engine was running on 100% peanut oil. |
| August 31, 1937 | A Belgian scientist, G. Chavane was granted a patent for a "Procedure for the transformation of vegetable oils for their uses as fuels. The concept of what is known as"biodiesel" today was proposed for the first time. |
| 1977 | A Brazilian scientist, Expedito Parente, applied for the first patent of the industrial process for biodiesel. |
| 1979 | Research into the used of transesterified sunflower oil and refining it to diesel fuel standards, was initiated in South Africa. |
| 1983 | The process for producing fuel-quality, engine-tested biodiesel was completed and published internationally. |
| November, 1987 | An Austrian company, An Austrian company, Gaskoks established the first biodiesel pilot plant. |
| April, 1989 | Gaskoks established the first industrial-scale plant. |
| 1991 | Austria's first biodiesel standard was issued. |
| 1997 | A German standard, DIN 51606, was formalized. |
| 2002 | ASTM D6751 was first published. |
| October, 2003 | A new Europe-wide biodiesel standard, DIN EN 14214 was published. |
| September, 2005 | Minnestosa became the first US state to mandate that all diesel fueled sold in the state contain part biodiesel requiring a content of at least 2% biodiesel. |
| October, 2008 | ASTM published new biodiesel blend specification Standards. |
| November, 2008 | The current version of the European Standard EN 14214 was published and supersedes EN 14214:2003. |

### *2.1. Sources (feedstocks) of biodiesel*

Biodiesel production is more convenient as an energy substitute due to its extensive available sources (feedstock). Types of biodiesel feedstock may differ from country to country and highly depends on their husbandry and geographical locations [23,24]. There are more than 350 oil-bearing crops identified, among which only soybean, palm, sunflower, safflower, cottonseed, rapeseed and peanut oils are considered as potential alternative fuels [17,44]. But in Malaysia the main feedstock for biodiesel production is palm oil [45].

However, some other non-edible oils such as *Karanja*, *Jatropha and neem* are winning worldwide attention. Selection of the best sources (feedstock) is cardinal to ensure lower cost for biodiesel production. More than 75% of the overall cost for biodiesel production covered by the supply of feedstock and price alone [46] as depicted in Fig. 2 [18,34]. Feedstock for the biodiesel production should be attainable at the possible lowest price and in an abundant with compare to ordinary diesel in the competitive market. Among all other properties of feedstock for biodiesel production favorable fatty acid composition, high oil content, low agriculture inputs (water, fertilizers, soils and

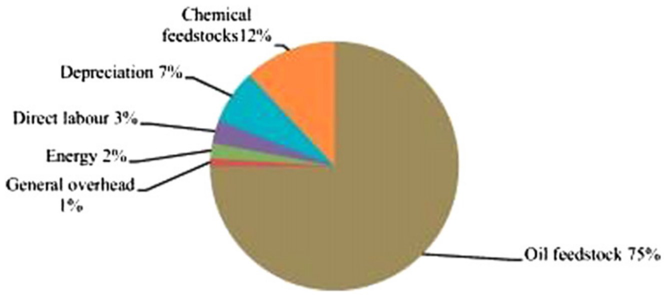



**Fig. 2.** General cost breakdown for biodiesel production.

pesticides), controllable growth and harvesting season, consistent seeds maturity rates and potential market for agricultural by-products are highly desirable [47]. In general, they can be divided into four main categories which are listed as below [18].

a. Edible vegetable oil—rapeseed, soybean, sunflower, palm and coconut oil.
b. Non-edible vegetable oil—Jatropha, Karanja, sea mango, algae and halophytes.
c. Waste or recycled oil.
d. Animal fats—tallow, yellow grease, chicken fat and by-products from fish oil.

### 2.2. Stability of biodiesel

Biodiesel which is produced from vegetable oils is considered more vulnerable to oxidation when subjected to high temperature and contact to the oxygen of the air, because of bearing the double bond molecules in the free fatty acid. Oxidative and thermal instability is the main classification of the chemical reactivity of fatty oils and esters which therefore can be ascertained by the amount and configuration of the olefinic unsaturation in the fatty acid chains. The biodiesel and its blends stability may incorporate following types of stability [22].

#### 2.2.1. Storage stability

Storage stability of biodiesel is considered as the resistance ability of liquid fuel in their physical and chemical characteristics during storage by the interaction with the surroundings [21].Therefore the resistance of biodiesel due to oxidative degradation during storage is significant subject for the sustainability and viability of alternative fuels. It is reported that by the interaction with light, contaminants and the factors which is responsible for changing colors, sediment formation and other changes which reduce clarity of fuel biodiesel stability may be impacted [48,49]. Many authors have executed the long term storage test and the effect of physical properties of the fuel with respect to time [50–54] and it was concluded that peroxide value, viscosity, density and acid value of biodiesel step ups with decreasing the combustion heat if biodiesel stored for 2 years which further leds to the formation of injector deposits, plugging of filters, fuel line, carbon deposits on piston and cylinder head [50–53,55].

#### 2.2.2. Oxidation stability

*2.2.2.1. Chemistry of oxidation.* Mainly oxidation occurs due to a set of reactions which is categorized as initiation, propagation and termination as shown in Fig. 3 [38]. It is seen that the first set (initiation) involves the removal of hydrogen from a carbon atom

**Initiation:** $RH + I \rightarrow R\cdot + IH$

**Propagation:** $R\cdot + O_2 \rightarrow ROO\cdot$

$ROO\cdot + RH \rightarrow ROOH + R\cdot$

**Termination:** $R\cdot + R\cdot \rightarrow R\text{-}R$

$ROO\cdot + ROO\cdot \rightarrow$ **Stable Products**

**Fig. 3.** Oxidation reactions.

to produce a carbon-based free radical. If diatomic oxygen is present, the subsequent reaction to form a peroxy radical is extremely fast, so fast as to not allow significant alternatives for the carbon-based free radical [56,57][22] J.C. Cowan, (3rd ed.), Wiley-Interscience (1979), p. 130–50… The peroxy free radical is not as reactive as carbon free radical but it is sufficiently reactive to abstract hydrogen from a carbon to form another radical and a hydroperoxids (ROOH). The new carbon free radical can then react with diatomic oxygen to continue the propagation cycle. This chain reaction terminates when two free radical react with each other in a termination step [58].

#### 2.2.3. Thermal stability

Thermal oxidation of biodiesel is termed as the rate of oxidation reaction by which oil and fat weight increases because of exposing to the high temperature (cooking temperature) [59,60]. The thermal stability of biodiesel could be defined as the resistance to thermal degradation. The higher the temperature, the faster is the oxidation process, i.e., higher rate of degradation of biodiesel [61]. It is involves the measurement of the tendency of a fuel to produce asphaltenes, when exposed to high temperature conditions. These asphaltenes are tar like resinous substances generated in the fuel and plug the fuel filters of the engines when used as fuel [62,63].

### 2.3. Biodiesel policies, standards and implementation

Most of the countries around the world have stated their biodiesel policies and standard which have been fixed recently. All countries have set the mandate or target for succeeding biodiesel consumption and their policies also have announced utilizing biodiesel in their energy mix. Some biodiesel target and mandate of different countries has been listed in Table 3 [19,25,26,64–75]. National biofuels policy of Malaysia has been set on 21 March 2006 which has shown in Fig. 4 [19,76] envisions:

- Use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels; and
- Enhanced prosperity and well being of all the stake holders in the agriculture and commodity based industries through stable and remunerative prices.
- The policy is primarily aimed at reducing the country's dependence on depleting fossil fuels, promoting the demand for palm oil and stabilizing its prices.

Actually Malaysian government had perceived the necessity of developing alternative energy resources especially on biodiesel in the long term since 1980s. Malaysia is raised as one of the

precursors in the palm biodiesel industry due to the largest producer and exporter of palm oil in the world [77]. In the transport sector of Malaysia, palm biodiesel were encouraged as an alternative fuel for adopting more renewable sources and not to be dependent on fossil fuels. Henceforth, biodiesel development in Malaysia had been growing rapidly. In 2006, the government launched the National Biofuel Policy to encourage the production and consumption of biodiesels and the government also declared a pledge to keep apart six million tonnes of crude palm oil for biodiesel production for supporting and make the policy successful. But due to the introducing of Envo diesel at the end of 2006, biodiesel status again solidified as a renewable energy source [78]. However the government turned back to the original mandate of using the B5 blend. Execution of B5 mandate was delayed to the middle of 2011 and it is limited to the Central Region [79]. Malaysia has obtained a satisfactory status herself in the proper truck to utilize biomass as a renewable energy source and it can act as a model to those countries in the world whose have an immense biomass feedstock [80]. At present Malaysia has 25 biodiesel plants with the total capacity of 2.6 million tonnes and most of these plants are located in Peninsula Malaysia [81]. Chronology of biodiesel development in Malaysia has shown in Table 4 [18,64,78,79,82].

**Table 3**
Summery of some biodiesel target and mandate of different countries.
*Source*: [19,25,26,64–75].

| Country | Official biodiesel target |
|---|---|
| Malaysia | Processed palm oil blend of 5% |
| Japan | 5% blend for biodiesel by 2010 |
| Thailand | 5% (B5) mix in 2007, 10% (B10) by 2011 and production of 8.5 million L per day by 2012 |
| Philippines | Coconut blend of 2% by 2009 |
| India | Meet 20% of the diesel demand beginning with 2011–2012 |
| Brazil | Minimum blending of 3% biodiesel to diesel by July 2008 and 5% (B5) by end of 2010. |
| China | Tax exemption for biodiesel produced from animal fat or vegetable oil |
| Taiwan | Directly subsidies or other tax exemptions (e.g., excise tax) for biodiesel |
| Canada | 2% renewable content in diesel fuel by 2012 |
| EU | Using 2% in 2005 and increasing in stages to a minimum of 5.75% by the end of 2010 and 20% by 2020. |

## 3. Practicability of *Jatropha curcas* as a biodiesel in Malaysia

Malaysia is one of the largest biodiesel producing countries [83] but biodiesel produced from Jatropha is still in its incipient state in Malaysia with comparing to palm oil biodiesel industry, even though great interest has been shown lately by both the private sectors and government sectors. Much attention has been drawn to the potential of using Jatropha as feedstock of biodiesel worldwide. In 2007 Goldman Sachs cited *Jatropha curcas* as one of the best candidates for future biodiesel production and biodiesel from Jatropha will be the cheapest biodiesel among the potential feedstock to produce biodiesel as shown in Table 5 [18].

*Jatropha curcas L.* has many vernacular names including: physic nut or purging nut it is also familiar as Ratan-jayot [35,42,84,85] and different name in different countries such as in Malaysia it is called as Jarak Pagar. In Malaysia, it can be produced in most parts because optimum temperatures for growing Jatropha are between 20 C and 28 C [86] which are similar to the average temperature of Malaysian environment. *Jatropha curcas* can be grown under a wider ranges of rainfall from 250 mm to 1500 mm per annum [87,88] but optimum rainfall between 1000 mm and1500 mm which correspond to sub humid region [89]. The plant Jatropha also can be adapted to prolific soil, good drainage and pH ranges from 6.0 to 8.5 [90,91].

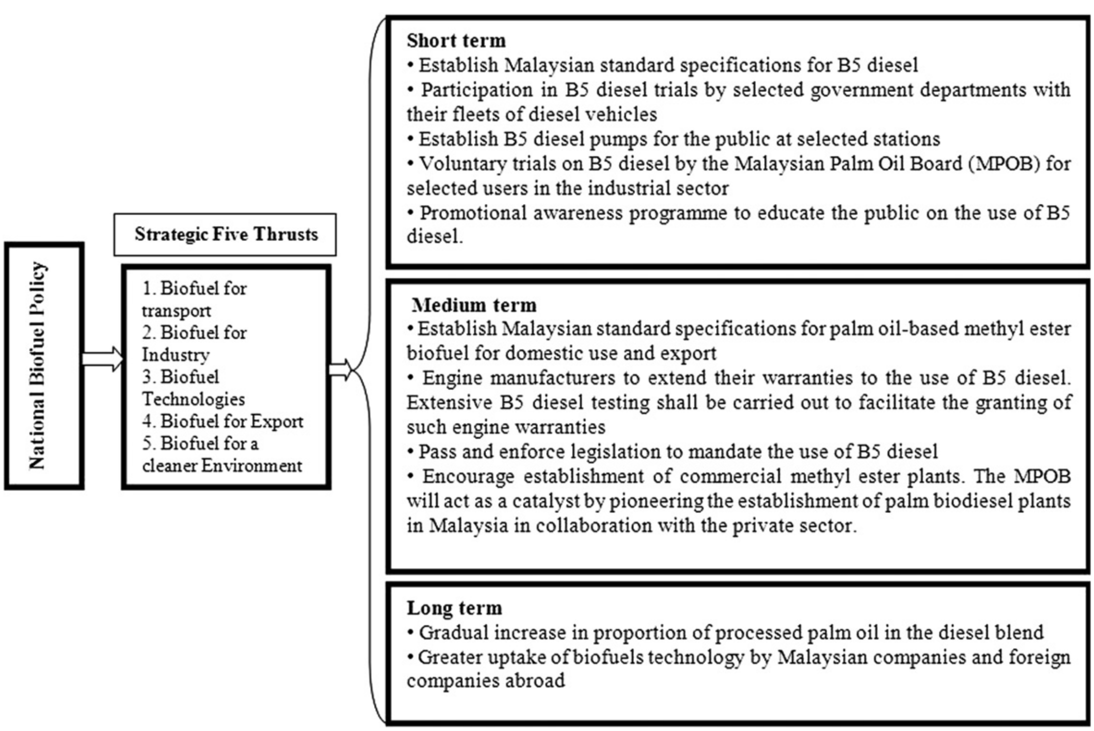



**Fig. 4.** Malaysia national biofuel policy and implementation.

**Table 4**
Chronology of biodiesel development in Malaysia.
*Source*: [18,64,78,79,82].

| Year | Milestone |
|---|---|
| 1982 | Laboratory research on palm methyl esters (PME) biodiesel began |
| 1983 | Palm Diesel Steering Committee formed by the Minister of Primary Industries |
| 1984 | Construction of a PME biodiesel pilot plant (3000 t a year capacity) began |
| 1984–1985 | Preliminary field trials in taxis conducted |
| 1985 | PME biodiesel pilot plant launched |
| 1986–1989 | Field trials phase I began—31 commercial vehicles and stationary engines |
| 1990 | Field trials phase II began—bench test by Mercedes Benz in Germany |
| 1990–1994 | Field trials phase III began—commercial buses |
| 1995 | Transfer of PME production technology to industry to produce oleo chemicals, carotenes (pro-Vitamin A) and Vitamin E |
| 2001 | Use of a CPO and fuel oil blend for power generation initiated<br>Research on low-pour-point palm biodiesel initiated |
| 2002 | Field trials using processed liquid palm oil and petroleum diesel blends (B2, B5, B10) in MPOB vehicles began (i.e., a straight vegetable oil [SVO] biofuel blend) |
| 2004 | Trials of refined, bleached and deodorized (RBD) palm oil and petroleum diesel blends (B5) using MPOB vehicles (i.e., an SVO biofuel blend) began |
| 2005 | Transfer of technology from the MPOB to Lipochem (M) Sdn Bhd and Carotino Sdn Bhd to build PME biodiesel plants<br>Design of commercial low-pour-point PME biodiesel plant<br>National Biofuel Policy drafted |
| 2006 | National Biofuel Policy launched<br>First commercial-scale biodiesel plant began operations<br>Envo Diesel launched<br>92 biodiesel licenses approved |
| 2007 | Increase in CPO price caused many biodiesel projects to be either suspended or canceled |
| 2008 | Malaysian Biofuel Industry Act 2007 came into force<br>Usage of Envo Diesel was scrapped and replaced with B5 |
| 2009 | Government vehicles from selected agencies began use of B5 blend |
| 2010 | Government announcement that the B5 mandate for commercial use will be deferred to June 2011 |

**Table 5**
Price comparison of biodiesel from different feedstock.
*Source*: [18]

| Feedstock | Price of crude vegetable oil(USD/tones) | Price of B100 Biodiesel (USD/tonnes) |
|---|---|---|
| Rapeseed [a] | 815–829 (Ex-Dutch Mill) | 940–965 (FOB NWE) |
| Soybean [a] | 735 (FOB Rosario) | 800–805 (FOB Rosario) |
| Palm oil [a] | 610 (Del. Malaysia) | 720–750 (FOB SE Asia) |
| Waste cooking oil [b] | 360 | 600 (estimated) |
| Animal Tallow [b] | 245 | 500 (estimated) |
| Jatropha [c] | N/A | 400–500 (estimated) |

[a] Source: Kingsman.
[b] Source: Rice.
[c] Source: Goldman Sachs.

### 3.1. Benefits and facilities of Jatropha curcas

*Jatropha curcas* is a succulent plant, small or large shrub tree, up to 5–7 m tall, belonging to the family of Euphorbiaceae [34,42,84,87,92–99] comprises around 800 species, which successively belong to some 321 genera. Jatropha is a drought resistant crop and its life expectancy is 50 years [85,92,96–98,100,101]. At the second year of the establishment it bears fruit and the economic maturity obtained in 3 to 5 years. Life cycle of *Jatropha curcas* is shown in Fig. 5 [102]. The fruit is a kernel which contains three seeds each and about 2–4 kg/seed/tree/year can be obtained. In poor soils, the yields have been reported to be about 1 kg/seed/tree/year [41,103]. The oil yields of *Jatropha curcas* is reported to be 1590 kg/ha [35,97,104,105].




**Fig. 5.** Life cycle of *Jatropha curcas*.

As per the analysis of various research publications *Jatropha curcas* own may attributes to be benefitted as biodiesel. Some of these advantages include:

- It is perennial, drought resistant and adapted for marginal land and can be used for halting and reversing land degradation.
- It is potentially productive in sandy, saline or otherwise infertile soil and it can be grown with very low costs.
- Jatropha grows fast and is easy to propagate (a cutting simply pushed into the ground will take root).
- It has capacity to stabilize sand dunes and combating desertification.
- Thrives well in tropical climates.
- It force back both the animals as well as insects naturally.
- Its harvest and maintenance is easy due small-sized and shady shrubs.
- The nutrients are not exhausted in the land.
- Fertilizers and expensive crop rotation not required to grow it.
- It grows in short period and establishes itself easily.
- It seed has a high oil yield (Jatropha can yield about 1000 barrels of oil per year per square mile—oil content of the seed is 55–60%).
- No need to displace the food crops.
- It is effective for developing countries in terms of energy and creation of jobs.
- The biodiesel byproduct glycerin is profitable in itself.
- After extracting oil the waste plant mass can be used as a fertilizer.
- The plant recycles 100% of the $CO_2$ emissions produced by burning the biodiesel.

- It can make good barrier hedge to protect crops having of unpalatable leaves.
- The oil can be used directly in lamps, cooking stoves as well as can be used for making soap, medicine and pesticides in different countries.
- It is believed that *Jatropha curcas* latex contains an alkaloid which known as “jatrophine” have anti-cancerous properties.
- A dark blue dye is produced by the bark of *Jatropha curcas* which is used for coloring cloth, fishing nets etc.
- The byproduct of *Jatropha curcas* has potential value using seed cake as fertilizers, animal feed or biogas.
- Its fruit shell and seed husk can be used to produce biogas which therefore can be used as cooking fuel.

### 3.2. Production and implementation of Jatropha curcas

A hectare of Jatropha cultivation has been claimed to acquire 2000 l of fuel annually [106,107]. Biodiesel production chain of *Jatropha curcas* has shown in Fig. 6 [42,53]. At present, the production and usage of *J. curcas* oil is no longer confined to a specific geographic region or a limited number of end-products. *Jatropha curcas* oil in large quantities is consumed globally, as a raw material of various products manufactured by a prominent number of industries. Different forms of *Jatropha curcas* utilization are depicted in Table 6 [98,108,109]. In many communities, the use of plant Jatropha has been found very suitable in different aspects. Besides using *J. curcas* oil as a biodiesel, soap and biocides (insecticide, molluscicide, fungicide and nematicide) also can be produced by the oil [109].

### 3.3. Properties and characters of Jatropha curcas

The properties of crude *Jatropha curcas* oil (CJCO) depend on the geographical location where it has been grown. The maximal amount of oil extraction from a given seeds highly depends on both the feedstock quality and the oil extraction method. Oil contents in *Jatropha curcas* more than soybean, linseed and palm kernel which has found 18.35%, 33.33% and 44.6% whereas oil contents in *Jatropha curcas* was reported at 66.4% and 63.16% in some other references [89,110]. Compared to others vegetable oil, Jatropha oil seed has highest oleic contain than palm oil, palm kernel, sunflower, coconut and soybean oil as shown in Table 7 [89]. Biodiesel from edible oils such as soybean, palm oil has a higher pour point compared to the

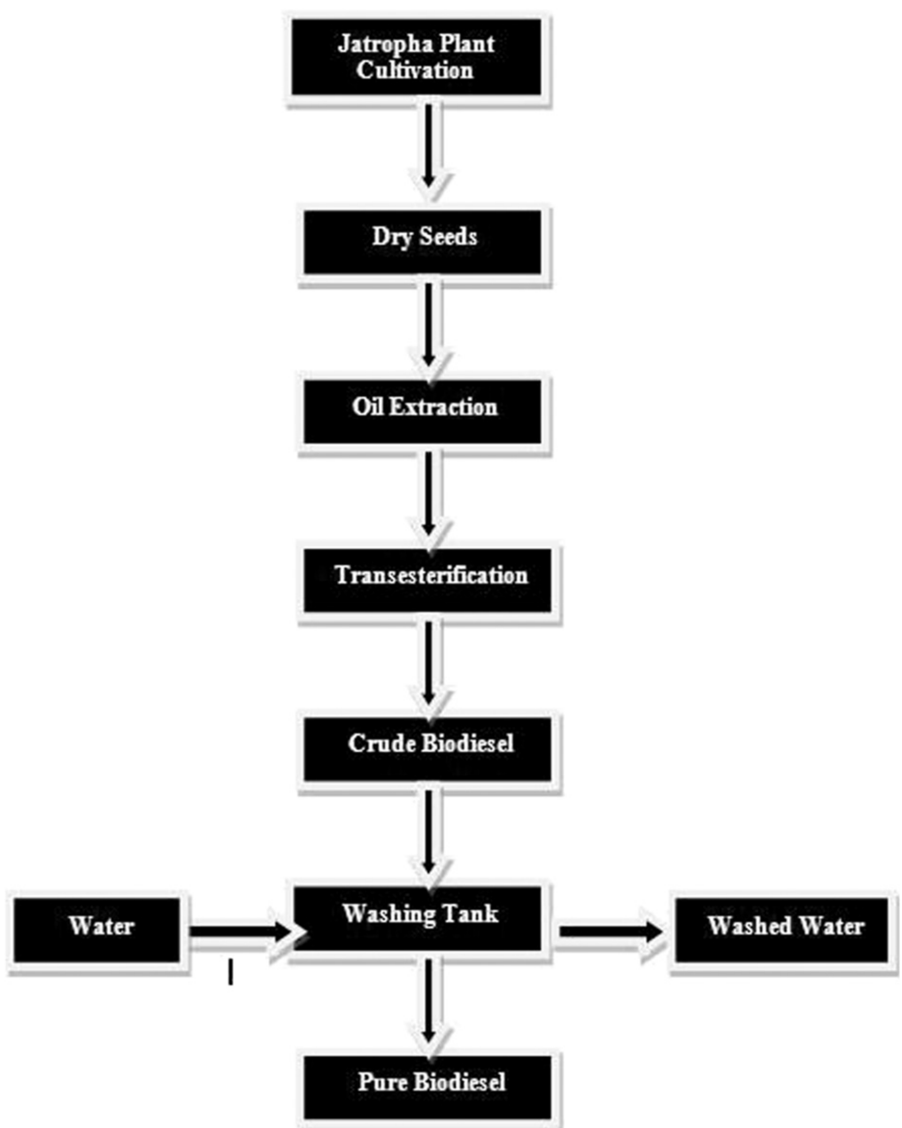



**Fig. 6.** Biodiesel production chain from *Jatropha curcas*.

**Table 6**
*Jatropha curcas* utilization in various forms.
*Source*: [98,108,109].

| Name of the Parts of the Jatropha | Usages |
|---|---|
| *Jatropha curcas* plant | Erosion control<br>Livestock fence<br>Support for vanilla crop<br>Green manure<br>Fuel wood<br>Combustibles<br>Soap<br>Detergents |
| Leaves | Medicinal uses Anti-inflammatory |
| Fruits | Soil ameliorant |
| Latex | Biogas production |
| Seeds | Wound healing |
| Fruit pericarp | Medicinal uses |
| Seed oil | Insecticide/molluscicide |
| Seed cake | Food/fodder |
| Seed husks | Soil ameliorant/mulch Biogas production Medicinal use Anti-infl amatory Fuel (Biodiesel/SVO) Soap making Insecticide/molluscicide Medicinal uses Organic fertilizer Biogas production Fodder Combustible fuel Organic fertilizer |

**Table 7**
Comparison among various feedstocks in terms of Fatty acid composition (%).
*Source*: [89].

| Fatty acid | *Jatropha curcas* oil seed | Palm oil[a] | Palm kernel oil[a] | Sunflower oil[a] | Soybean oil[a] |
|---|---|---|---|---|---|
| Oleic | 44.7 | 39.2 | 15.4 | 21.1 | 23.4 |
| Linoleic | 32.8 | 10.1 | 2.4 | 66.2 | 53.2 |
| Palmitic | 14.2 | 44.0 | 8.4 | – | 11.0 |
| Stearic | 7.0 | 4.5 | 2.4 | 4.5 | 4.0 |
| Palmitoleic | 0.7 | – | – | – | – |
| Linolenic | 0.2 | 0.4 | – | – | 7.8 |
| Arachidic | 0.2 | – | 0.1 | 0.3 | – |
| Margaric | 0.1 | – | – | – | – |
| Myristic | 0.1 | 1.1 | 16.3 | – | 0.1 |
| Caproic | – | – | 0.2 | – | – |
| Caprylic | – | – | 3.3 | – | – |
| Lauric | – | 0.2 | 47.8 | – | – |
| Capric | – | – | 3.5 | – | – |
| Saturated | 21.6 | 49.9 | 82.1 | 11.3 | 15.1 |
| Monounsaturated | 45.4 | 39.2 | 15.4 | 21.1 | 23.4 |
| Polyunsaturated | 33 | 10.5 | 2.4 | 66.2 | 61.0 |

[a] Carbon in the chain: double bonds.

*Jatropha curcas* oil. Therefore, it is functional in some four season's countries also [111]. Some properties of Jatropha oil and Jatropha methyl esters are compared with ASTM D6751 and EN 14214 specifications have been given in Table 8 [33,42,109].

### 3.4. Performance of compression ignition engine when operated with the blends of Jatropha oil/biodiesel and diesel

In many countries Researchers have tried to determine and compare the performance of compression ignition engines by using Jatropha oil/biodiesel and diesel under similar condition. In CI (compression ignition) engines the use of crude Jatropha oil is a practicable alternative to diesel [112] but the combustion of crude Jatropha oil instead of biodiesel is less energy efficient and causes problems to the engine. It has been reported from the properties and engine test results Jatropha biodiesel can be used as diesel substitute without any modification of the engine [113–115]. Some key chemical and physical properties of Jatropha oil and its blends relative to diesel fuel have been shown in Table 9 [112,116]. But it is also reported that atomization, injection and combustion characteristics of the oil from Jatropha tend to digress due to few unusual properties & it demands for refinement further. Some important engine performance parameters (i.e., brake power, specific fuel consumption, torque, emission and brake thermal efficiency, etc.) using different blends of Jatropha and diesel from different countries as well as various research outcomes are presented in Table 10 [41,112,117,118].

## 4. Current status of *Jatropha curcas* as a biodiesel resource in Malaysia

Malaysia has adequate area of land and good climatic condition which can promote the cultivation of Jatropha to be one of sources of biodiesel production. Malaysia is taking on the challenge to further explore and strengthening the Jatropha production initiative through partnership with the government agencies and with private sectors. This effort is a vision to set Malaysia to the forefront of the global alternative fuel producers.

At the beginning, a total of 1712 ha land areas were identified for primary production of Jatropha in Malaysia. A few local private companies engaged in Jatropha cultivation scaling from 400 ha to 1000 ha. Project owners are expecting to increase the cultivation up to a total of 57,601 ha by 2015. The Ministry of Plantation of Industries and Commodities undertook a Jatropha pilot project for which 300 ha had been allocated. Some international leading oil companies are investing to develop Jatropha projects in Malaysia too.

**Table 8**
Comparison of Jatropha oil and Jatropha methyl esters properties with ASTM D6751 and EN 14214 specifications.
*Source*: [33,42,109].

| Properties | Jatropha oil | JME | Diesel | ASTM D 6751 | EN 14214 |
|---|---|---|---|---|---|
| Density at 15 °C (kg/m$^3$) | 918 | 879 | 850 | 860–900 | 875–900 |
| Kinematic viscosity at 40 °C | 35.4 mm$^2$/s | 4.84 cSt | 2.6 | 3.5–5.0 mm$^2$/s | 1.9–6.0 mm$^2$/s |
| Acid value (mg KOH/g) | 11 | 0.24 | 0.35 | 0.5(Maximum) | 0.5 (Maximum) |
| Flash point°C | 186 | 191 | 70 | > 101 (Minimum) | 130 (Maximum) |
| Cetane number | 23 | 51 | 46 | 51 (Maximum) | 47 (Minimum) |
| Sulfated ash | – | 0.014 wt% | – | 0.02 wt% | 0.02 wt% |
| Water | 5% | 0.16 mg/kg | 0.02 | 0.05 mg/kg | 0.05 mg/kg |
| Conradson Carbon residue | 0.3 | 0.025 | 0.17 | < 0.30% m/m | < 0.050 wt% |
| Iodine number (g/100 g) | 101 | 86.5 | – | < 120 | – |
| Free glycerol | – | 0.015 wt% | – | 0.02 wt% | 0.02 wt% |
| Total glycerol | – | 0.088 wt% | – | 0.24 wt% | 0.25 wt% |
| Calcium | – | 6.1 | – | 5 ppm (Maximum) | 5 ppm (Maximum) |
| Magnesium | – | 1.4 | – | 5 ppm (Maximum) | 5 ppm (Maximum) |

**Table 9**
Chemical and physical properties of Jatropha oil and its blend relative to diesel fuel.Source: [112,116].

| Properties | Units | Fuel blend | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0/100 | 50/50 | 70/30 | 80/20 | 90/10 | 95/5 | 97.4/2.6 | 100/0 |
| Density | kg/m3 | 917.7 | 891.7 | 909.6 | 876.9 | 856.2 | 849.4 | 868.4 | 866.9 |
| Kinematic viscosity | cSt | 36.9 | 14.6 | 7.9 | 8.2 | 5.4 | 4.9 | 5.9 | 5.7 |
| Flash point | °C | 99 | 94 | 167 | 90 | 133 | 125 | 88 | 86 |
| Pour point | °C | −3 | 6 | 11.8 | 12 | 11.3 | 12.8 | 15 | 15 |
| Calorific value | Mj/kg | 42.048 | 43.099 | 39 | 44.15 | 40.4 | 42.3 | 45.202 | 45.90 |

**Table 10**
Comparative engine performance with blend of Jatropha biodiesel and diesel in different countries.
*Source*: [40,112,117,118].

| | Name of the country | | | | |
|---|---|---|---|---|---|
| | Malaysia | Indonesia | India | Bangladesh | Thailand |
| Engine Model | Mitsubishi 1988 cc,4 cylinder IDI Diesel Engine | Motor Diesel Chang chai,SX175 | Single Cylinder open combustion CI Engine | 4 cylinder In line air cooled diesel cycle engine | ISUZU EFI 250 truck 2369cc diesel 4 cylinder water cooled |
| % of Blend use | B20 | B40 | B50 | B50 | B30 |
| Engine Speed | 1500 | 1600 | – | – | 2000 |
| Brake Power(KW) | 18 | 1.47 | – | 0.399 | 2249 |
| Torque(N-m) | 102 | 9000 | – | – | 107.33 |
| Brake Thermal | 32 | 43 | 22.44 | 10.18 | – |
| efficiency (%) | – | – | – | – | – |
| Brake Specific fuel consumption (g/Kwh) | 280 | – | 693 | 1298 | 300 |
| | – | – | – | – | – |

**Table 11**
Potential area for plantation of Jatropha in Malaysia.
*Source*: [120].

| Region | Area (million acres) |
|---|---|
| Peninsular Malaysia | 8.5 |
| Sabah | 10.4 |
| Sarawak | 14 |

Being one of the premiers in Jatropha research, The Malaysian Rubber Board (MRB) is cheering up the farmers to produce the Jatropha in waste and marginal lands. The land in which cost-effective production is not possible due to soil productivity, cultivation techniques and other factors is called marginal land [119]. Production of Jatropha in such lands will not make any hindrance in production of rubber and palm. Some local private companies have been conducting researches on *Jatropha curcas* genomics too. Nevertheless, National Tobacco Board was confided to estimate the practicability of cultivating the plant Jatropha on bris soil in the northern part of the country in 2007. Plantation of Jatropha was primarily originated in East Malaysia with scattered small-scale plantations before 2008 and less than 40,000 ha land was used at that time. In 2008, 80,000 ha farmland had been contracted by Mission Biotechnology to grow *Jatropha curcas* in Malaysia. It was anticipated that the total land area will increase up to 0.6 million hectares and 1 million hectares by the end of 2009 and 2010, respectively [18].The potential area for plantation of *Jatropha curcas* in Malaysia has given in Table 11 [120] and also shown in Fig. 7 [120]. At present, Bionas Group is encouraging people to participate in *Jatropha curcas* planting efforts providing an affordable and innovative development program, offering an opportunity to everyone to plant Jatropha in sustainable and commercial scale. The Company has successfully developed Jatropha planting in 3.3 million acres by contracting with thousand of land owners in the country. The total allocated land is 500 thousand acres for Phase 1 of this program. Under this program, the participants are offered the opportunity to purchase Jatropha seedlings and plantation fertilizers amounting to RM 3000 from Bionas Sdn. Bhd. (BSB) [120].



**Fig. 7.** The potential plantation area for *Jatropha curcas* in Malaysia.

It is reported that in Malaysia the development of the plant Jatropha will grow at a moderate rate in the near future as Malaysian government is not eager to emphasis more on Jatropha which may interrupt its own palm oil plantation equilibrium while at the same time does not wish to lose out on any convenience it may offer to the local biodiesel industry.

## 5. Impact of biodiesel from *Jatropha curcas*

As the biodiesel is mainly extracted from the agro-based products, its utilization in mass consumer sector faces many challenges. Though biodiesel is creating the pavement to lessen the threat of scarcity in fuel sources, various researches have pointed out that the industrial application of biodiesel may have

an impact on available food production due to increase of day to day demand of biodiesel in consumer levels. Jatropha is a non-edible product and fortunately it possesses the amicable fuel properties. Due to good climatic condition and availability of land, Jatropha can be one of the good choices for biodiesel industries in Malaysia. The impact of biodiesel from *Jatropha curcas* in terms of environmental, emissions and socio-economic considerations are presented in the following sections.

### 5.1. Environmental consideration

Production of biodiesel is a complex task in considering to long term environmental effect. Life-cycle reductions in carbon-dioxide emissions depend on the source of the feedstock, production pathways and the assumptions made for alternative uses of the land from which the feedstock was produced, especially if the land had previously been forested. In case of the conceived feedstock the green house gas emission balancing is particularly difficult to check. The uncertainty is because of nitrous oxide emissions associated with growing oil bearing plants. These are dependent on the rate of nitrogen fertilizer application. In this context Nitrogen fixing plants, non-leguminous plants like Jatropha have been found to be more acceptable [121]. If the energy output of a given system is greater than the energy input, the system has a positive energy balance. However, energy balance is affected by energy quality and the utility of different energy carriers. The production of Jatropha biodiesel reportedly has a positive energy balance. The plant Jatropha possesses most pleasing characteristics of sustaining drought and spring up in waste and marginal lands with low rainfall and inadequate soil fertility [85,87]. A growing demand for bioenergy creates increased requirements for water for irrigation of biofuel crops and conflicts between water use for energy and use for other agricultural production are becoming an issue. Jatropha's main advantages are its resistance to drought and its low water requirements. The ability to grow Jatropha under dry conditions and increase the vegetation cover on degraded land gives opportunities for channeling of water, which earlier evaporated from the ground, into positive transpiration [139,140].

The plant Jatropha may be used to limit soil degradation [101,122]. Particularly the seedcake of *Jatropha curcas* can be used to improve the land properties in semi-arid areas too. Moreover, *Jatropha curcas* plant founded as one of the oxygen generating plants which return to ozone. As a natural fence, farmers can be served by the plant Jatropha in restraining conflicts with imperiled wildlife. In addition by providing physical barriers, Jatropha can control grazing and demarcate property boundaries while at the same time improving water retention and soil conditions. These attributes, added to the benefits of using a renewable fuel source, can contribute in an even larger way to protecting the environment. The production of Jatropha biodiesel releases less greenhouse gas (GHG) emissions compared to production of fossil diesel. Prueksakorn and Gheewala [123] found that 90% of the total life-cycle GHG emissions are caused by the end-use. They calculated that the global warming potential of the production and use of *Jatropha curcas* bio-diesel is 23% of the global warming potential of fossil diesel. The main reason for this is that biodiesel is produced from biomass, and its carbon dioxide (CO2) emissions from combustion in the engine are considered GHG neutral. Although extensive research is needed to determine and manifest these affects over the whole life cycle of growing, energy production and utilizations. In general, present research suggests that the production of biodiesel from Jatropha is considered to be prescribed with compare to the usage of petroleum derived diesel, although the particular methods of growing, transporting and processing are responsible to the implication of this positive energy balance which tends to be project specific. Toxicity of *Jatropha curcas* may cause environmental and public health problems. It is reported that the oil contain curcanoleic acid, which may lead skin cancer and also may induce skin vexation to the farmers [124]. In South Africa, Hawaii, Australia and many other countries of the world Jatropha is also considered as invasive [125].

### 5.2. Emissions and socio-economic consideration

Biodiesel contain higher oxygen compared to petroleum diesel and the use of biodiesel in diesel engines have shown majestic reductions in emanation of CO, sulphur, PAH, smoke, PM and noise. However, it emits more NOx emission than diesel [19,26,48,114,126–129]. The emission of $SO_2$, soot, CO, hydrocarbons (HC), polyaromatic hydrocarbons (PAH) and aromatics etc from biodiesel with compare to diesel fuel are given in Fig. 8 [38], the observation indicates that the engine exhaust contains no $SO_2$ and shows decreasing emissions of PAH, soot, CO, HC and aromatics. Biodiesel from vegetable oil does not contain any metals, sulfur or crude oil residuals that outstandingly lead on reduction of acid rain by not passing off sulfuric acid and sulfates in the atmosphere.

The average emission changes found by EPA for B20 and B100 is depicted in Table 12 [126,127]. It has also been reported that biodiesel and its blends emit lower level of specific toxic compound such as PAH, aldehydes and nitro-polyaromatic hydrocarbons [34,130,131]. The $CO_2$ emission factor of biodiesel is 70,800 kg/TJ which is 4.67% higher than diesel fuel [132]. Moreover, the potential mitigation of $CO_2$ emission developed from replacement of biodiesel in the long term and middle term is shown in Table 13 [133].

Substituting biodiesel for conventional fossil fuels is widely considered to have societal benefits, such as reducing greenhouse gas emissions and supporting rural agricultural economies.

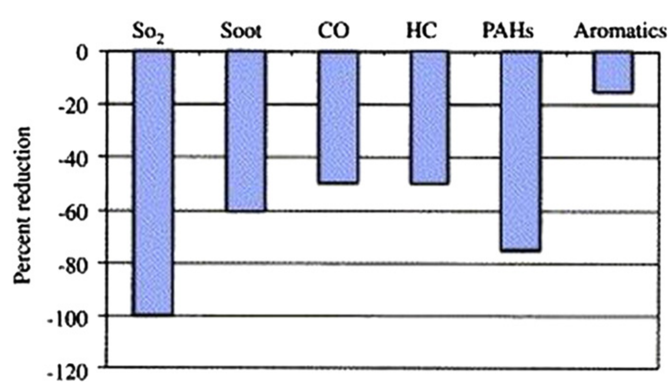



**Fig. 8.** Biodiesel emission compared with diesel fuel.

**Table 12**
Average heavy-duty emission impact of 20% and 100% biodiesel relative to average conventional diesel fuel.
*Source*: [126,127].

| Air pollutant | Change for B20 (%) | Change for B100 (%) |
|---|---|---|
| NOx | +2.0 to −2 | +10 |
| PM | −10.1 | −47 |
| CO | −11.0 | −48 |
| Hydrocarbon | −21.1 | −67 |
| Sulfates | −20.0 | −100 |
| PAH | −13 | −80 |
| (polycyclic aromatic hydrocarbons) | – | – |
| nPAH (nitrated PAH's) | −50 | −90 |

**Table 13**
Potential mitigation of $CO_2$ emission from biodiesel.
*Source*: [133].

| Parameter | Unit/year | Middle term (2010–2015) | Long term 2015–2025 |
|---|---|---|---|
| Substitution | Ton oil | 6000,000 | 16,000,000 |
| Mitigation | Million ton | 19 | 50 |
| emission $CO_2$ | | 0.12 | 0.98 |

Jatropha oil returns more than expenses and labor to the owner. The setting-up of *Jatropha curcas* oil extracting industries may reduce the unemployment by creating job opportunities as well as provide a great income source for both the farmers and suppliers of feedstock and provide a lot of revenue to the governments. Also, it will offer independency on petroleum-derived fuels and lower the import costs of crude petroleum [134]. With the demand for *Jatropha curcas* biodiesel (as like palm Biodiesel) there will be comprehensive commercial plantation of *Jatropha curcas* in Malaysia. Therefore, *Jatropha curcas's* potential to promote Malaysia from developing country to developed country is very high. Existing wisdom gaps and ambiguous economic point, together with competition on the global biofuels market, may bias *Jatropha curcas* investor away from marginal or degrade lands towards agricultural or lands that are valuable for biodiversity. Some economic significance of *Jatropha curcas* is described by Kumar and Sharma [93]. Jatropha needs resources like other crops to attain high productivity so that it can reduce financial risk [130]. Malaysia has focused on the development of *Jatropha curcas* and other non-food graded biodiesel crops to discover and evolve high-yielding feedstock source that may play a great role to change the conventional farming system to be introduced with bioenergy per hectare of land. *Jatropha curcas* has an immense contribution in improving rural livelihoods too. Poverty springs from a lack of income and assets, and particularly a lack of empowerment that limits livelihood options. The cultivation of Jatropha for seed production expands livelihood options with the opportunity to earn income for smallholder growers, oil mill out growers and members of community plantation schemes or through employment on private enterprise Jatropha plantations. Women especially can benefit, because milling machines powered by diesel engines fueled with Jatropha oil reduce the amount of tedious work they must do. Using Jatropha oil as a replacement for traditional biomass cooking fuels is also healthier, as cooking is done in a smoke free environment, and women do not have to spend time gathering fuel wood. The decreased need for fuel wood also relieves pressure on forest resources. Small businesses in the rural non-farm sector can become more efficient with availability of a cheaper and more dependable fuel source, for example to power cutting and grinding machinery. Using Jatropha oil to fuel irrigation pumps and two-wheeled tractors can increase agricultural efficiency [135]. Some potential advantages of *Jatropha curcas* and its product have been shown in Fig. 9 [136]. Local communities may obtain maximum benefits not only from the plant Jatropha and its product but also through oil extraction. Better extraction technique can be applied to improve the raw oil extraction process which subsequently may increase the biodiesel production economy.

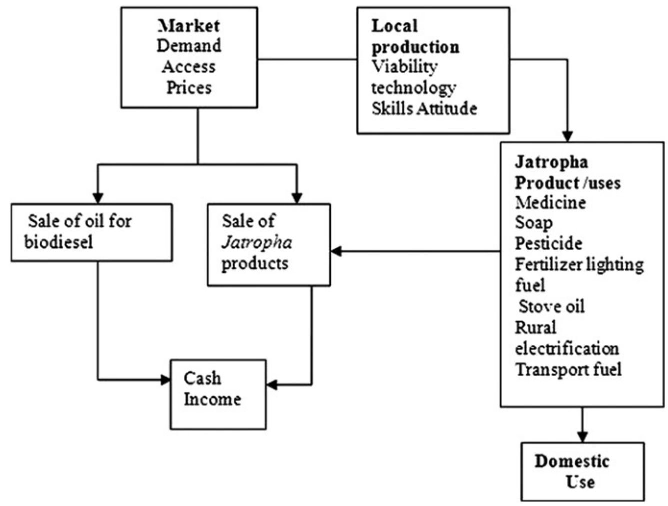



**Fig. 9.** Potential advantages from *Jatropha curcas*.

## 6. Biodiesel market development in Malaysia

Malaysia is developing in biodiesel market due to a number of reasons, communities self participation in the production, interest in increasing income and get rid from the destitution. Besides this, increasing fossil fuel price and target for reducing green house gases (GHG) emissions also influences the communities to develop biodiesel market in Malaysia.

Malaysia is one of the highest biodiesel producers in the world. The government is motivating private companies to establish more treating plants and upgraded biodiesel for vehicles and electricity generation. Government of Malaysia has kept the biodiesel industry growth at the top of their agenda by providing sufficient subsidy and farmer support programs. Currently the number of using vehicles is indicated by the registered vehicles from 1996 to 2009. Post estimate for diesel vehicles account for about 5% of the motor vehicle population in Malaysia. The Malaysian Automotive Association (MAA) forecasts total industry volume of motor vehicles to recover from a small drop in 2009. Table 14 [137,138] forecasts a healthy growth till 2014.

Post estimation showed that diesel vehicles could make up a greater share of the total in the future when B5 is introduced and Government incentives are promoted. The annual road tax which drivers must have to pay is always higher for diesel engine vehicles because of considering diesel engines to release more harmful emissions into the environment. On January 1, in 2007 the Government of Malaysia reduced the annual road tax for petroleum vehicles with engine capacities less than 1600 $cm^3$ (c.c.) by 10% while the tax for diesel vehicles with engine capacities less than 1600 c.c. was reduced by 34% [137].

## 7. Conclusion

From the literature it can be concluded that biodiesel is an environmentally friendly fuel which can be used in diesel engines without any modification. As a biodiesel feedstock Jatropha provide sustained green house gas facilities over other biodiesel fuels. Jatropha is claimed: not to compete with food, not to compete with agricultural land, not to compete with nature, enhance rural economics and reduce green house gasses. *Jatropha curcas* has been found more promising for biodiesel production due to some attracting characteristics such as its ability to give better yield and productivity of oil; it is the cheapest biodiesel source among other sources. Biodiesel from Jatropha oil has a comparable cetane number with diesel fuel which meets the ASTM standards and can be used in diesel engine with similar or better performance.

**Table 14**
Malaysian Automotive Association (MAA) Forecast of vehicle sales
*Source*: [137,138]

| | 2009 | 2010 | 2011 | 2012* | 2013* | 2014* |
|---|---|---|---|---|---|---|
| Passenger vehicles | 486,342 | 498,300 | 514,500 | 530,500 | 546,000 | 562,400 |
| Commercial vehicles | 50,563 | 51,700 | 52,000 | 53,000 | 54,000 | 55,600 |
| Total Industry volume | 536,905 | 550,000 | 566,500 | 583,500 | 600,000 | 618,000 |
| Growth | 2.0% | 2.4% | 3% | 3% | 2.8% | 3% |

* Forecast.

*Jatropha curcas* can be the future biodiesel source for Malaysia and Malaysian government has taken initiative to fortifying Jatropha production through partnership with the government agencies and with private sectors due to lower production cost, barrier for escalation of vegetable oil prices in accordance with palm oil, addresses the global demand for biodiesel. It is expected that biodiesel production from Jatropha will increase substantially due to mass feedstock, good climatic condition and availability of land. This will offer a safe environment by reducing carbon emissions. Mass oil production from Jatropha will bring a positive growth as well as development of biodiesel. Jatropha oil biodiesel has potential to bring Malaysia from developing to developed country. Therefore, proper strategies and government incentives are to be prompted to enhance the use of biodiesel fuel especially in road transport sector and electricity generation rather to increase only biodiesel production. Keeping in view, government should take step to avoid the use of edible oil to produce biodiesel due to a big gap in the demand and supply of such oils for dietary consumption in many countries but need to put more emphasizes on non edible oil source like Jatropha.

## Acknowledgment

The authors would like to acknowledge University of Malaya for financial support through High Impact Research Grant entitles: Clean Diesel Technology for Military and Civilian Transport Vehicles which Grant number is UM.C/HIR/MOHE/ENG/07.

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